11.3 The Kidney & Osmoregulation

Question Paper

Course	DP IB Biology
Section	11. Animal Physiology (HL Only)
Topic	11.3 The Kidney & Osmoregulation
Difficulty	Hard

Time allowed: 70

Score: /56

Percentage: /100

Question 1a

a)
Contrast the renal cortex and the renal medulla.

[3 marks]

[3 marks]

Question 1b

b)
Nephrotic syndrome is a condition that causes the kidneys to leak large amounts of protein into the urine. This can lead to a variety of problems, including swelling of body tissues and an increased risk of catching infections.

Suggest why research into cures for nephrotic syndrome are focused more on the components of the basement membrane than on those of the endothelial layer within a glomerular complex.

[2 marks]

[2 marks]

Question 1c

c)
A well-documented effect of antidiuretic hormone (ADH) is the increase in permeability of the distal convoluted tubules and collecting ducts to water, thereby allowing more water to be reabsorbed at times of low blood water content.

There is also a secondary osmoregulatory effect of ADH; this takes place on arterioles.

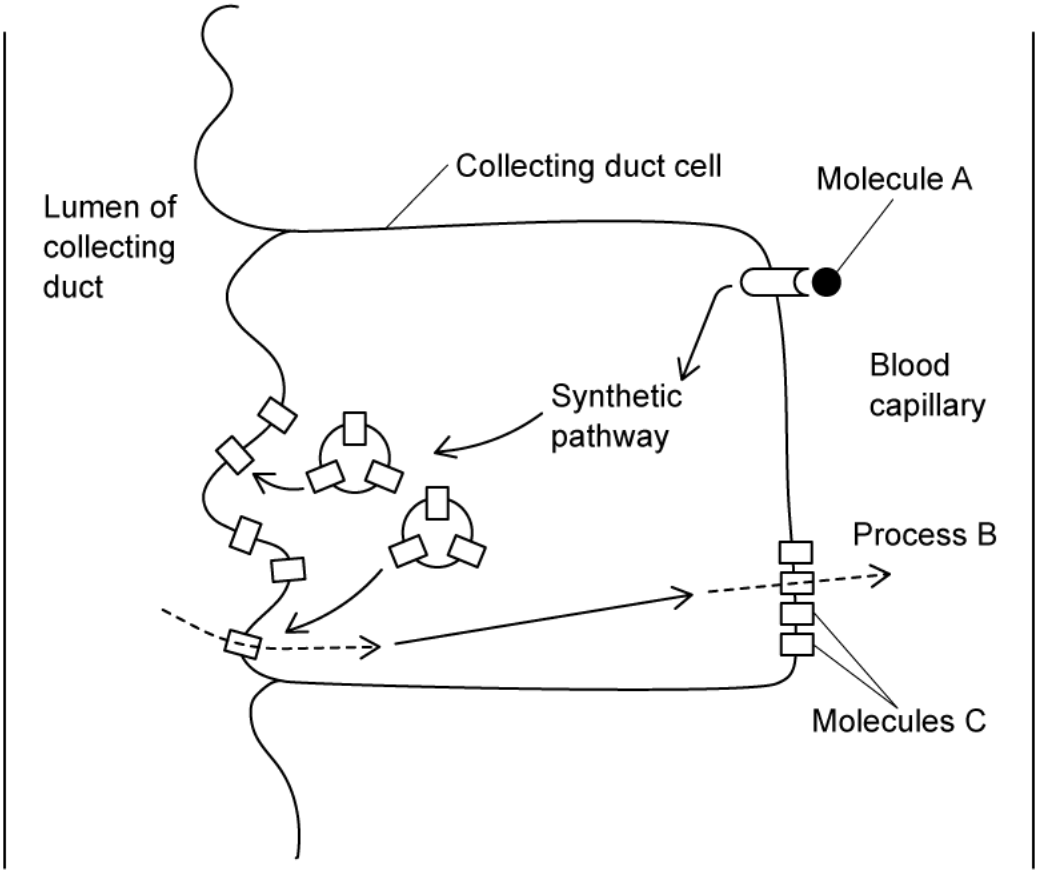
Suggest what this effect is and give a reason for your suggestion.

[2 marks]

[2 marks]

Question 1d

d)
The diagram shows a sequence of events involved in osmoregulation.



Identify Molecule **A**, Process **B** and Molecules **C**.

[3 marks]

[3 marks]

Question 2a

a)
One effect of an ageing population is the increase in deaths and health complications from dehydration in the elderly, many of whom lack a thirst response when partially dehydrated.

A study was performed to examine the effect of ethanol ('alcohol') consumption on the urine output of a group of elderly men.

Ethanol is a known diuretic.

Define the term diuretic and outline its mode of action.

[2 marks]

[2 marks]

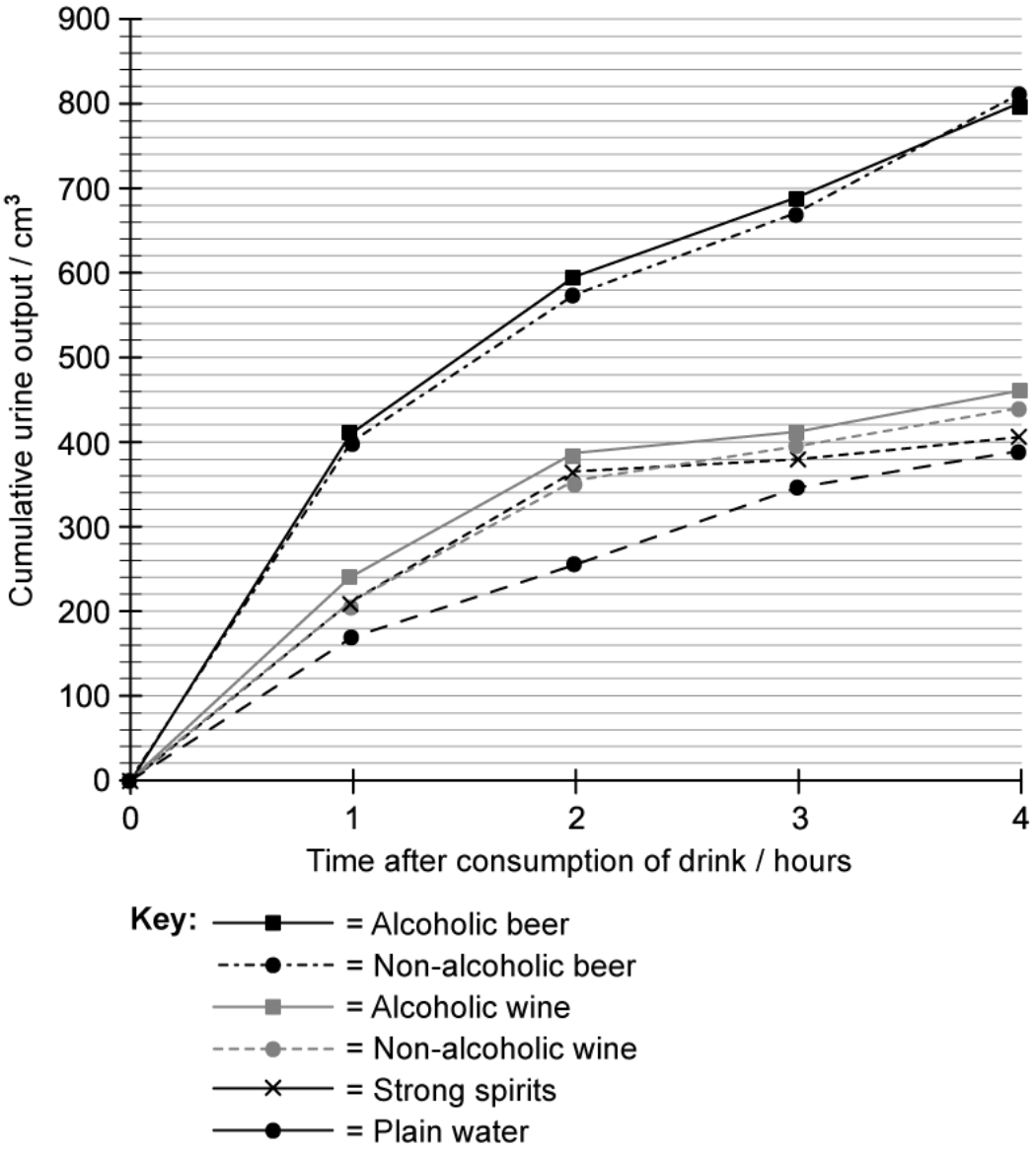
Question 2b

b)

In the study referred to in part a), a group of 20 elderly men (age range 65–75) were given the same diet and were optimally hydrated before the study. All the men consumed no alcohol for 48 hours prior to the experiment. At the beginning of the study,

- one subgroup was given alcoholic beer, another non-alcoholic beer
- one subgroup was given alcoholic wine, another non-alcoholic wine
- one subgroup was given strong spirits, another plain water
- for the men given alcoholic drinks, an equivalent volume of ethanol was consumed in each case
- for the men given non-alcoholic drinks, the same volume was consumed as for their alcohol-containing counterparts

In each case, the men's average cumulative urine output was measured over the 4 hours following consumption of the drinks. The results are shown below.



Calculate the percentage difference between the urine produced in the first hour by men drinking alcoholic beer versus those drinking alcoholic wine.

[2 marks]

[2 marks]

Question 2c

c)
The researchers conducting the study concluded that drinking beer of any variety contributed more to dehydration than any other choice of drink.

Evaluate this conclusion.

[6 marks]

[6 marks]

Question 3a

a)
Organisms that live in a saltwater environment face extreme osmoregulatory challenges.

Suggest why it is so difficult for marine mammals to maintain the correct osmotic balance in their blood.

[2 marks]

[2 marks]

Question 3b

b)
The table below contains information about several marine mammals and their osmoregulatory mechanisms. Humans have been added for comparison purposes, and seawater sodium concentration has also been included.

Organism	Habitat	Primary water source	Urine osmolarity / mol dm^{-3}	Na^+ concentration / mmol dm^{-3}
Human	Terrestrial	Drinking fresh water	1400	20
West Indian Manatee	River (but can survive in marine)	Diet/metabolism	1158	31
Sea otter	Marine	Drinking sea water	2130	505
Elephant seal	Marine	Diet/metabolism	1850	297
Seawater	*N/a*	*N/a*	*N/a*	*470*

Suggest how sea otters are able to drink seawater and still maintain osmotic balance.

[3 marks]

[3 marks]

Question 3c

c)
Manatees are unusual marine mammals in that they are able to spend time in both saltwater and freshwater environments.

Research into osmoregulation in manatees shows that levels of a hormone called aldosterone change when the manatee's environment changes. Aldosterone is known to activate a sodium transporter protein in the cells lining the nephron.

Suggest how the saltwater and freshwater environments might affect aldosterone levels and explain how this could help the manatee regulate its ion balance.

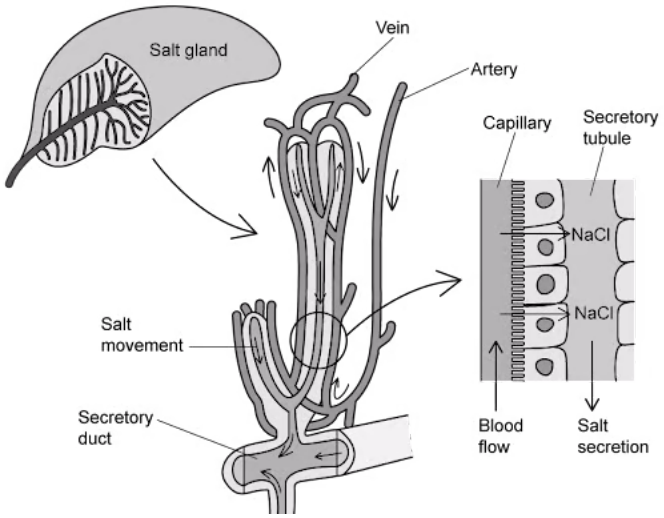
[3 marks]

[3 marks]

Question 3d

d)
Sea birds do not osmoregulate in the same way as marine mammals. They excrete nitrogenous waste via highly concentrated uric acid, and excrete excess salt separately via salt glands.

The diagram below shows the structures within the salt glands, where a countercurrent mechanism involving capillaries and salt secretory tubules removes excess salt to an external secretory duct.



Explain how the countercurrent system ensures maximum salt excretion from the blood of sea birds.

[2 marks]

[2 marks]

Question 4a

a)
The glomerulus is a structure in the kidneys responsible for the process of ultrafiltration. Explain how ultrafiltration would be affected by severe dehydration.

[2 marks]

[2 marks]

Question 4b

b)
An important role of the kidneys is the removal of urea from the blood. The amount of urea removed from the blood can be used as a measure of the rate of ultrafiltration, also known as the glomerular filtration rate (GFR).

An individual excreted 540 mg of urea from the blood over the course of 1 hour, and has a blood urea concentration of 0.01 mg cm^{-3} entering the kidneys. Use this information to calculate this person's GFR.

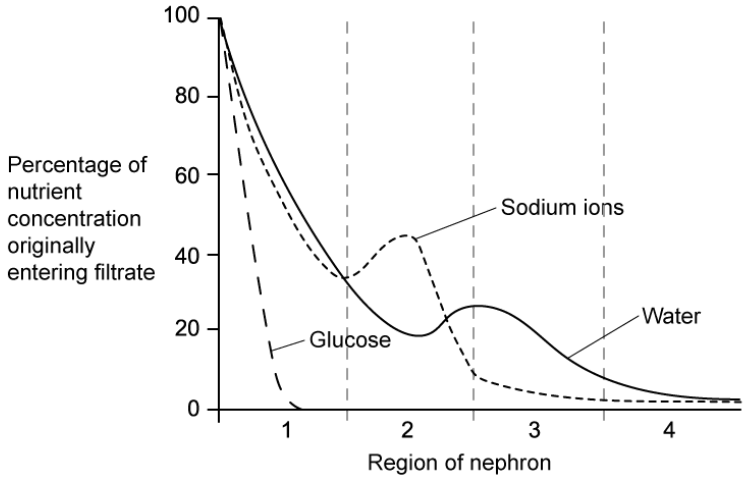
State your answer in cm^3 min^{-1}.

[2 marks]

[2 marks]

Question 4c

c)
After ultrafiltration, the filtrate travels through the kidney nephron. The graph below shows what happens to various components of the glomerular filtrate as they move through the different regions of an individual's nephron.



Describe and explain the shape of the curve for sodium ions and water as they travel through region 2 of the nephron as shown in the graph.

[4 marks]

[4 marks]

Question 4d

d)
Explain how the plotted line for water in region 4 of the graph in part (c) would look different if the ADH concentration in this individual's blood were to decrease.

[3 marks]

[3 marks]

Question 5a

One mark is available for clarity of communication throughout this question.

a)
Draw and label a diagram of a human kidney.

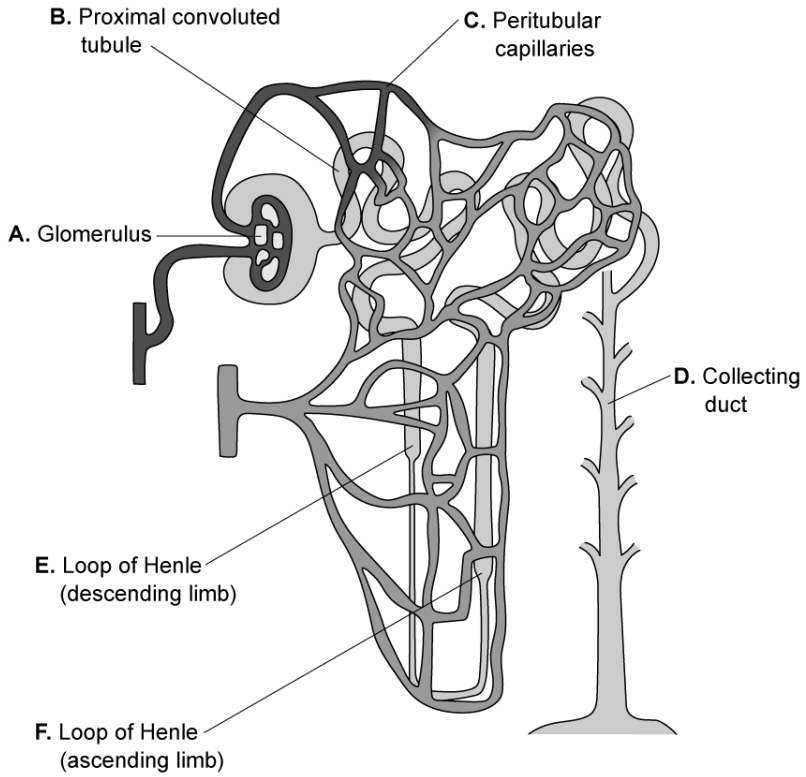
[6 marks]

[6 marks]

Question 5b

b)

The diagram below shows a human nephron and its associated blood supply.



Annotate the labels **A – F** shown to explain briefly the functions of the various parts of the nephron.

Label	Structure	Annotation
A.	Glomerulus	
B.	Proximal convoluted tubule	
C.	Peritubular capillaries	
D.	Collecting duct	
E.	Loop of Henlé (descending limb)	
F.	Loop of Henlé (ascending limb)	

[6 marks]

[6 marks]

Question 5c

c)
Kidney patients on a course of haemodialysis treatment are advised to increase their protein intake and limit the amount of ions (eg. potassium, phosphorus, sodium) and fluid in their diets.

Suggest **three** reasons for this dietary advice.

[3 marks]

[3 marks]